Description

<u>Method for operating a radio system as well as emitting station and</u>
<u>radio system</u>

5   The invention relates to a method for operating a radio system with
    at least some stations which are equipped with a directional antenna
    as well as to a corresponding emitting station and a corresponding
    radio system.

    In radio systems both signaling data and organizational information
10 (for example control signals or information about the quality of the
    connection) and also payload data (for example speech, picture
    information or other data) is transmitted by means of
    electromagnetic waves over a radio interface between sending and
    receiving station.

15 Radio systems are for example cellular mobile radio systems such as
    GSM (Global system for Mobile communications) and UMTS (Universal
    Mobile Telecommunications System). Here data and data packets are
    transmitted by means of base stations which define a cellular
    structure from the fixed network over an air interface to mobile
20 stations. The base stations in such cases have omnidirectional
    antennas, i.e. antennas which emit in all spatial directions and/or
    directional antennas which make it possible to emit the radio
    signals in a defined direction.

    Furthermore Wireless Local Area Networks (WLANs) are known, for
25 which two basic modes of operation exist:

    1. Access to other networks and thereby data transfer between
       different radio networks is made possible by an infrastructure
       network. The infrastructure network can additionally be

responsible for the control of access to the network components
of the networks involved.

2. A network in the form of a self-organizing network (also called
   an ad-hoc network) dispenses with a network infrastructure.

5   Subscriber devices of a ad-hoc network can communicate with each
    other provided they are in the mutual radio area or further
    subscriber devices can forward the data. Access to other networks
    is possible in combination with an Infrastructure network.

If a wireless local area network is implemented using an
10 infrastructure network there is communication between subscriber
devices and access points, with the access points, as well as
controlling the radio transmission, also establishing the connection
to other wired or wireless networks.

In ad-hoc networks a number of subscriber devices are able to
15 establish a radio connection between themselves even without access
points. The connection between two subscriber devices is made here
either directly or over longer distances via further similar
subscriber devices which form relay stations for these connections.
The subscriber devices of a ad-hoc network can be mobile stations
20 (for example mobile radio devices of people or in vehicles) and/or
primarily stationary stations (for example computers, printers, home
appliances). Ad-hoc networks are implemented for example in wireless
local area networks such as HiperLAN and IEEE 802.11. Such wireless
local area networks are not only used in the normal Internet and
25 telematics area but also in the area of communication between
vehicles, such as for example in hazard warning systems or
cooperative driver assistance systems.

In ad-hoc networks with a frame structure access to the radio
interface is in transmission frames. In this case a first subscriber
device signals during the signaling phase of a transmission frame
with a request-to-send the time interval in which it wishes to
5   transmit data in the subsequent data transmission phase of the
transmission frame. Further subscriber devices in the radio area of
the first subscriber device which also wish to transmit during the
data transmission phase of the time frame receive the information
about the time interval and reserve further consecutive time
10   intervals in the data transmission phase. The individual time
intervals are arranged next to each other within the data
transmission phase of the transmission frame. The maximum volume of
data which can be sent during a data transmission phase of a
transmission frame is determined in this case by the length of the
15   data transmission phase. In an extreme case only one subscriber
transmits per data transmission phase so that the subscribers are
distributed over a number of data transmission phases. Thus
transmission pauses of several data transmission phases can occur
for the individual subscribers.

20   In Y.-B. Ko et al.,„Medium Access Control Protocols Using
Directional Antennas in Ad Hoc Networks", Proceedings of the IEEE
INFOCOM 2000, March 2000, a Request-To-Send (RTS) is transmitted
from a first station to a second station via a directional antenna
in an ad-hoc network, in which all stations possess a number of
25   directional antennas. Together with the request-to-send the first
station transmits its physical position as well as the duration of
the data transmission. If the second station acknowledges the
request-to-send the first station transmits its data to the second
station for the specified duration. If a third station receives the
30   request-to-send from the first station, the third station blocks its
directional antenna which is pointing in the direction of the first
station during data transmission from the first station to the
second station. Directional antennas which are not pointing in the

direction of the first station during data transmission from the
first station to the second station can be used by the third
station.

R. R. Choudhury describes in „Using Directional antenna for Medium
Access Control in Ad hoc Networks", Technical Report of Texas A&M
University to BBN Technologies, March 2002, an ad-hoc network with
stations with antenna systems which can be operated in omni mode or
directional mode. Omni mode means that exclusively reception is
omnidirectional, i.e. omnidirectional transmission is not possible.
Directional mode means that both transmission and reception are
possible in respect of a specifiable direction. A first station
wishing to send sends a request-to-send in the direction of a second
station. Since all stations of the ad-hoc network have antennas
which can determine on the basis of a received signal the direction
from which the signal came, the second station can also use a
directional antenna pointing in the direction of the first station
to acknowledge the request-to-send to the first station. The first
station then sends data to the second station. If another station
which is in omni mode receives the request-to-send of the first
station, it computes the direction from which the first signal came
and prevents itself transmitting data in the direction of the first
station while the latter is transmitting data to the second station.

Transmission resources can also be seized in the way described in
the article by Soheila V. Bana and Pravin Varaiya, „Space Division
Multiple Access (SDMA) for Robust Ad hoc Vehicle Communication
Networks", IEEE fourth international conference on intelligent
transportation systems, on the basis of a geographical position of a
station with a request-to-send. This article describes an SDMA
method in which each geographical position or area is assigned a
time interval or a frequency on a one-to-one basis. If a station
with a request-to-send is assigned a certain time interval, the
temporal position of the time interval relative to further time

intervals is produced directly by the geographical position of the
station with the request-to-send.

The object of the invention is to specify a method with which
transmission resources can be better utilized.

5   This object is achieved by the method with the features according to
Claim 1, the emitting station in accordance with Claim 13 and the
radio system in accordance with Claim 14.

Advantageous embodiments and developments of the invention are the
subject of the dependent claims.

10 In the inventive method for operating a radio system with stations,
a first emitting station is equipped with a directional antenna. The
first emitting station provides for transmission of data to a first
receiving station by means of the directional antenna in a first
spatial radio area and broadcasts directional information which
15 reveals the spatial direction in which it is providing for the
transmission of the data. On the basis of the broadcast directional
information transmission resources can advantageously be seized. For
example, with a centrally-controlled access method a control station
which receives corresponding directional information from a number
20 of stations can take account of this directional information for the
occupation of transmission resources by the stations. Furthermore a
control station in a locally-organized system can receive the
directional information of a number of stations and forward it in a
broadcast to all stations or itself seize transmission resources
25 corresponding to the directional information.

If a second emitting station in particular receives the directional
information, the directional information is advantageously taken
into account for its occupation of transmission resources. The

second emitting station can for example favorably seize transmission resources for its own data transmission.

If the second emitting station is equipped with a directional antenna and it provides for transmission of data to a second
5   receiving station by means of its directional antenna in a second spatial radio area, it is advantageous for the second emitting station to check on the basis of the directional information of the first emitting station whether the first and the second spatial radio area overlap at one of the receiving stations. The first and
10   second emitting station can then transmit their data in accordance with the invention such that the transmission only occurs simultaneously if the first and the second spatial radio area do not overlap at any of the receiving stations. In this way, in the event of the first and second radio areas being suitable, data which
15   without the invention would have to have been transmitted consecutively can be transmitted simultaneously.

An especially advantageous embodiment of the invention is produced if the second emitting station (also) broadcasts directional information from which the spatial direction in which it provides
20   for the transmission of its data can be derived. Further stations now have the opportunity of receiving the directional information of the first and second emitting station and can seize their transmission resources by evaluating the two items of directional information.

25   In a further embodiment of the invention the stations of the radio system broadcast position information about their geographical position. This signal can be received by all stations and can be used together with directional information from emitting stations for occupying transmission resources, especially for checking the
30   overlapping of the spatial radio areas.

Advantageously the first emitting station broadcasts information
about a time interval provided for transmission of its data to the
first receiving station. Stations which receive this information
then know how the first emitting station is planning the timing
5   sequence of its data transmission.

If the second emitting station also sends information, after
checking the overlapping of the first and second spatial radio area,
about a time interval provided for transmission of its data to the
second received station, both time intervals can be taken into
10· account by the stations which have received the broadcast of the
first and the second emitting station for the occupation of their
transmission resources.

In a further advantageous embodiment of the invention the direction
information specifies the geographical position of the emitting
15   station in each case and the relevant spatial direction in which the
signals are to be radiated. Stations which receive this type of
direction information thus have a current geographical position of
the emitting station available to them in each case and have a lower
processing overhead since the relevant spatial direction in which
20   the signals are emitted can be taken directly from the direction
information and does not have to be computed.

It is further of advantage for the direction information to
alternatively or additionally specify the geographical position of
the relevant receiving station. In this way a possible current
25   geographical position of the receiving station can be used for
checking the overlapping of the radio areas.

In a radio system in which different types of directional antennas
are used it is expedient for the direction information to contain
antenna information about the characteristics of the directional

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antenna used. The radiation characteristics of the antenna used can than be read off directly from the antenna used and can be used to determine the associated radio area.

The invention can be executed advantageously if the radio system is

5   a cellular or a wireless local area network.

Advantageously at least one of the emitting stations and/or at least one of the receiving stations is a mobile station.

The emitting station and the radio system are equipped with the components necessary for executing the method.

10   The invention is explained below on the basis of exemplary embodiments shown in the Figures. The Figures show:

Fig. 1:   a first operating state of a radio system operating in accordance with the inventive method,

Fig. 2:   of a second operating state of the radio system,

15   Fig. 3:   a emitting station in accordance with the invention

The invention will be described below with reference to an ad-hoc network. Naturally the invention can also be used in other radio systems. This applies especially to wireless local area networks as well as to GSM, UMTS and 4th-generation mobile radio systems.

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The same reference symbols identify the same objects in the Figures.

In the scheme shown in Figure 1 a first emitting station MS1 and a
second emitting station MS2 are depicted, as well as a first
receiving station MS3 and a second receiving station MS4. The
sending and the receiving stations MS1, MS2, MS3, MS4 each have a
directional antenna RA and an omnidirectional antenna OA. If the
receiving stations MS3, MS4 also have the same equipment which
allows the emitting stations MS1, MS2 to execute the invention, the
receiving stations MS3, MS4 can function in their turn as emitting
stations. Likewise the emitting stations MS1, MS2 can be used as
receiving stations if they have the same equipment as the receiving
stations MS3, MS4.

The first and second emitting station MS1, MS2 as well as the first
and second receiving station MS3, MS4 each have a GPS receiver (GPS:
Global Positioning system) to determine their geographical position
(x_1,y_1), (x_2,y_2), (x_3,y_3), (x_4,y_4). The stations of the radio system
MS1, MS2, MS3, MS4 broadcast position information GI which contains
their geographical position (x_1,y_1), (x_2,y_2), (x_3,y_3), (x_4,y_4) in each
case by means of their omnidirectional antennas OA. Broadcast in
this case means sending out (broadcasting) information. The
broadcast sent by a station can be received by all stations which
are located in the radio coverage area of the station.

In a given radio system the geographical position of a station of
the radio system can of course also be determined and broadcast by a
central control station and and/or transmitted to the station for
broadcasting.

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With their adjustable directional antenna RA the emitting stations
MS1, MS2 emit radio signals in a freely selectable spatial direction
$\vec{R}_1$, $\vec{R}_2$. The aperture under which the electromagnetic radiation is
emitted is specified in this case by the antenna characteristics and
5   is for example encoded in an identification number of the relevant
directional antenna RA.

The first emitting station MS1 transmits data D1 by means of its
directional antenna RA to the first receiving station MS3. The data
D1 is transmitted in a spatial direction $\vec{R}_1$ and in a first spatial
10   radio area F1. The first spatial radio area F1 of the first emitting
station is in this case determined by its geographical position
(x_1,y_1), by the spatial direction $\vec{R}_1$, in which the data D1 is
transmitted and by its antenna characteristics. The data D1 is
transmitted in a time interval Z1, which lasts from time t_0 to tine
15   t_1. Simultaneously the second emitting station MS2 transmits data D2
to a second receiving station MS4 in a time interval Z2 which lasts
from time T_0 to time t_2. The second emitting station MS2 transmits
the data D2 to the second receiving station MS4 in a spatial
direction $\vec{R}_2$ and in a second spatial radio area F2. The second
20   spatial radio area F2 of the second emitting station MS2 is defined
in this case by its geographical position (x_2, y_2), by the spatial
direction $\vec{R}_2$, in which the data D2 is transmitted, and by its
antenna characteristic.

The first and the second emitting station MS1, MS2 transmit their
25   data D1, D2 at least partly simultaneously. In the data transmission
no interference can occur between the first and the second emitting
station MS1, MS2 since the first and second spatial radio area F1,
F2 do not overlap at any of the receiving stations MS3, MS4.

In an ad-hoc network which is not combined with an infrastructure
30   network there is no central device controlling the occupation of

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transmission resources. The stations of an ad-hoc networks thus
organize the timing of their data transmission themselves.

To divide up the transmission resources which result from the data
transmission described, the first emitting station MS1 broadcasts
5   its request-to-send via its omnidirectional antenna OA. With the
request-to-send the first emitting station MS1 also sends
directional information RI, from which the spatial direction in

which $\bar{R}_i$ it provides for the data D1 to be transmitted is derived.
The notation RI(AI) in Figure 1 shows that antenna information AI
10   about the characteristics of the directional antenna RA is contained
in directional information RI Direction information RI further
contains information ZI about the time interval Z1 provided for
transmission of data D1. The broadcasts of the first emitting
station MS1 are received by the second emitting station MS2 and used
15   for the occupying transmission resources, i.e. for the definition of
the relative timing position of time intervals Z1, Z2.

The second emitting station also checks whether the first spatial
radio area F1, which it can determine by means of the direction
information RI and the antenna information AI that it contains about
20   the characteristics of the directional antenna RA of the first
emitting station MS1, overlaps at one of the receiving stations MS3,
MS4 with the second spatial radio area F2. If there is an overlap
the second emitting station MS2 places its time interval Z2 behind
the time interval Z1 of the first emitting station to avoid
25   interference. If there is no overlap, as shown in Figure 1, the
first and the second emitting station MS1, MS2 begin transmission of
their data D1, D2 at the same point in time t_0. Of course the time
intervals Z1, Z2 can also begin at different points in time, with
the second emitting station MS2 however placing the position of the

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time interval Z2 so that there is the greatest possible overlap
between time intervals Z1, Z2.

Before the first and the second emitting stations MS1, MS2 transmit
their data D1, D2 the second emitting station also sends direction

5   information RI from which the spatial direction $\vec{R}_2$ in which it is
providing for the transmission of its data D2 can be taken. The
direction information RI in its turn contains antenna information AI
about the characteristics of the directional antenna RA as well as
information ZI about the time interval Z2 provided for transmission

10   of the data D2. The broadcasts of the first and second emitting
station MS1, MS2 are then received at further stations and used by
these to seize their transmission resources. This is shown
schematically in an example using a third emitting station MS4 in
Figure 2 which is described later.

15   The broadcast direction information RI of the first emitting station
MS1 reveals the spatial direction $\vec{R}_1$ in which it wishes to transmit
its data D1. To this end the direction information RI contains its
geographical position (x_1, y_1) and the geographical position (x_3, y_3) of
the first receiving station MS3. From this the second emitting

20   station MS2 can compute the spatial direction $\vec{R}_1$ in which the first
emitting station MS1 would like to transmit its data D1. If the
direction information RI contains only the geographical position
(x_3, y_3) of the first receiving Station MS3, the second emitting
station MS2 can obtain the geographical position (x_1, y_1) of the first

25   emitting station MS1 from the broadcast position information GI.
Naturally the direction information RI can also identify just the
first sending MS1 and the first receiving station MS3. The second
emitting station MS2 can then, on the basis of the position
information GI broadcast beforehand in any event by all stations

30   MS1, MS2, MS3, MS4 of the radio system, determine the spatial
direction $\vec{R}_1$. Furthermore the direction information RI can naturally

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also directly specify the geographical position $(x_1\ y_1)$ of the first

emitting station and the spatial direction $\vec{R_1}$, i.e. the direction

vector $\vec{R_1}$.

With regard to the antenna information AI, it should be noted that,
5   without adversely affecting the executability of the invention, this
can also be transmitted separately from the direction information
RI.

What was stated above naturally applies to the direction information
RI of the second emitting station MS2 as well as of further emitting
10   stations.

In the schematic diagram shown in Figure 2 (crosses indicate the
sending and receiving stations MS1, MS2, MS3, MS4 here), which shows
another operating state of the radio system from Figure 1, in
addition to the first and second emitting station MS1, MS2, the
15   second receiving station MS4 also transmits data D3 to the first

receiving station MS3 in a spatial direction $\vec{R_3}$ and in a third

spatial radio area F3. As already described for the data
transmission of the first and second emitting stations MS1, MS2, the
second receiving station MS4 receives the request-to-send messages
20   of the first and second emitting station MS1, MS2 before the start
of the data transmission and defines the time interval Z3 of its
data transmission so that there is no interference with the data D1,
D2 of the first and second emitting station MS1, MS2.

The first and the third spatial radio area F1, F3 overlap at the
25   first receiving Station MS3 so that the first emitting station and
the second receiving station MS4 may not transmit data D1, D3
simultaneously. Nor may the second emitting station MS2 transmit
simultaneously with the second receiving station, since the second
receiving station MS4 cannot simultaneously receive data D2 and
30   transmit data D3. For the reasons given, the second receiving
station MS3 places its time interval Z3, which lasts from time t_2 to

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time t_3 in time behind time interval Z1, Z2 of the first and second emitting station MS1, MS2.

The exemplary embodiments shown can easily be transferred to radio systems with any number of stations, so that the embodiment of the invention is naturally not restricted to a radio system with four stations.

An inventive emitting station MS which at the same time features all the equipment of a receiving station is shown schematically in Figure 3, so that each emitting station of an inventive radio system can also be used as a receiving station and vice versa.

The emitting station MS has an omnidirectional antenna OA for sending and receiving radio signals, especially for sending inventive broadcasts. Furthermore the emitting station MS features a directional antenna RA with which it can explicitly send data D to a receiving station. The information ZI_e received through the omnidirectional antenna OA and a transmitter and receiver unit SE about time intervals, direction information RI_e and position information GI_e of other stations of the radio system, is evaluated in a unit P together with the own direction information RI_s of the emitting station MS, i.e. a check is made as to whether the radio area of the emitting station MS overlaps with radio areas of other stations. Data transmission of the emitting station is determined in accordance with the result of this check and unit P then notifies a send unit S when and in which direction the data D is to be transmitted to a receiving station.

The emitting station MS also has a unit M with which it determines its own direction information RI_s which reveals the spatial direction

in which the emitting station MS is providing a transmission of the data D. Further units, not shown, which can however - as in this exemplary embodiment - also be integrated into unit M, determine position information GI_s and antenna information of the emitting

5   station MS as well as information ZI_s about the time interval in which the data D is to be transmitted. All information RI_s, GI_s, ZI_s is transmitted to the send and receive unit SE which then broadcasts said information.